LAB WORK, PILOT TRIALS AND BRAINS TRUST DELIVERING FRESH SUPPLY FOR THRIVING TOWNS

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ABSTRACT

Improvements to the drinking water supplies are necessary to deliver compliant drinking water for the growing communities of Alexandra and Clyde in Central Otago, New Zealand. In addition, Central Otago District Council confirmed their desire to pursue a treatment solution which provides 4-log inactivation for protozoa, with residual chlorination to achieve bacterial compliance. The Lake Dunstan Water Supply project delivers on these needs by combining the benefits of a well selected water treatment technology and supply system, and a collaborative design and procurement model.

A pilot trial in 2018 showed that treating the raw water via cartridge filtration, UV disinfection and chlorination was not feasible. This was primarily due to fine suspended solids ('glacial rock flour') causing the cartridge filters to rapidly blind and this technology is not backwashable. Lindavia diatom algae was also observed in the filters which presents risks of "lake snow" polysaccharides further blinding filters. Stantec completed a broad review of available treatment options for the specific challenges observed. Two filtration treatment options were subsequently pilot trialed in 2020:

- Cartridge filtration combined with Arkal/Amiad pre-treatment system
- Membrane filtration

The pilot trials have yielded the following key results:

- Disc filter plus microfibre filter pre-treatment was not able to remove sufficient material to protect and prolong the cartridge filter run time. The resulting requirement for frequent replacement of cartridge filters ruled out this option.
- Membrane filtration performed well at removing rock flour and algae concentrations.
- Operating flux rates, backwashing frequency and chemical cleaning regime to inform later stages of design.
- The bores installed within the constructed embankment demonstrate good filtering of lake snow.
- Raw water sampling confirmed low concentrations of dissolved iron and dissolved organics. The requirement for coagulant chemical dosing and/or pre-treatment upstream of the membranes as part of initial works was therefore excluded.
- Further treatment trials are recommended at other localities in Central Otago to challenge test the pilot plant under high lake snow conditions.

With the treatment technology confirmed, the project team have embarked on a collaborative design process involving broad technical and contractor input. This is resulting in an efficient scheme with the different parties challenging each other along the way. This is delivering the benefits of a lean design and Design and Build Contract whilst ensuring

appropriate risk reduction. To date the project team has delivered significant smart solutions, some of which are noted below:

- Review of network flow data has allowed for a reduction in the WTP capacity when combined with storage capacity at Alexandra Northern Reservoir site upsized to 6,000 m³. The resulting required plant capacities of 14 MLD from 2023 and 20 MLD from 2028 are well matched to the design capacities of the membrane skids (7 MLD each).
- Removal of DAF pre-treatment system anddentification of future upgrades to respond to potential changes in raw water quality.
- Reservoir material selection assessment. Concrete v bolted steel tank.
- Removal of additional filtrate tank and booster pumps by matching the site layout and scheme hydraulics to the membrane feed pump hydraulic capacities.
- Reduction of flows to wastewater system by discharging backwash waste to Clutha River under Permitted Activity rules.

This paper summarises the critical benefits and outcomes from the pilot trials and collaborative design process.

KEYWORDS

Drinking Water Quality, Science, Procurement and Project Delivery

1 INTRODUCTION

Significant population growth and the need for improved water supply safety under the New Zealand Drinking Water Standards requires a new water supply system including water extraction, treatment, conveyance and storage upgrades for the communities of Clyde and Alexandra.

The investigations and design work to date have included hydraulic modelling, demand assessments and multiple pilot trials with the findings being used to refine the design basis to ensure the water supply system is reliable, resilient, compliant with the new Drinking-water Standards for New Zealand 2005 (Revised 2018) and is adaptable to meet the growing needs of the community for many years to come.

The collaborative multiple organization design team is delivering designs with significant value engineering wins, resilience benefits and future proofing details that will ultimately provide for a low TOTEX cost efficient scheme.

This paper outlines the scheme details, the team utilized, the benefits obtained through the investigation phase and the delivery processes that are allowing for project successes to be realized.

2 BACKGROUND AND PILOT TRIALS

2.1 PILOT TRIALS

A concept design for the new Lake Dunstan Water Supply (LDWS) for Clyde and Alexandra was developed in 2017. The proposed treatment process comprised cartridge filtration followed by UV disinfection and chlorination. Central Otago District Council (CODC) subsequently engaged Stantec in 2018 to implement the proposed solution, including detailed design and procurement. At the time of tendering, Stantec recommended CODC consider carrying out a pilot trial to confirm the technical feasibility of using cartridge filtration to treat bore water sourced from Lake Dunstan.

Cartridge filter pilot trials undertaken in the summer of 2018/2019 resulted in rapid blinding of the cartridge filters (i.e., <5 days). Microscopic analysis showed the blinding was due to a 'new' organism, Lindavia, with other organic and mineral deposits including glacial rock flour. The conclusion drawn from the initial pilot trials is that the proposed cartridge filter solution for the water treatment process was not feasible.

During early 2019 discussions also took place between Stantec and Queenstown Lakes District Council (QLDC), which identified that QLDC have similar problems with Lindavia in Lake Wakatipu and Lake Wanaka, and that both CODC and QLDC could benefit from collaboration and undertaking of a combined pilot trial programme.

In April 2019, Stantec prepared a table titled 'Lake Dunstan Water Supply Pilot System Option Summary' (Options Summary Table). The table identified other alternative feasible treatment processes that were considered suitable for the final scheme. A workshop was held in August 2019 involving CODC, QLDC, Dr. Colin Fricker and Stantec to review the Options Summary Table. The purpose of this workshop was primarily to confirm that all potential and suitable treatment process options had been identified, and secondly to identify the options that were the most likely to be suitable for CODC given the current understanding of water treatability issues (including Lindavia and lake snow). Pilot trials were deemed necessary to both prove the technical feasibility of the treatment options and enable detailed design and optimisation of the full-scale plant.

Two treatment options were selected to pilot trial in the first instance:

Option 1 – Cartridge Filtration; comprising pre-treatment (Arkal Spin Klin and Amiad AMF) + cartridge filters

Option 2 – Membrane Filtration; comprising pre-treatment (DAF) + membranes

Following evaluation of the pilot plant quotations in November 2019, it was decided to remove the DAF pre-treatment stage from the pilot trials. This was not considered to be a significant issue on the basis that the membrane backwash system combined with cleaning regime was expected to be able to remove lake snow. This is further discussed in Section 5 below

The membrane trial (Option 2) commenced at Lake Dunstan on 4 February 2020 and the cartridge trial (Option 1) commenced on 13 March 2020. The trials were carried out in parallel, treating the same water source at the same time. The raw water was sourced from Bore 1 for the first 1-2 months, before trailing direct extraction from Lake Dunstan (i.e., theoretically a 'poorer' water quality) for the remainder of the trial.

Both trials were interrupted during the Covid 19 lockdown. The cartridge filter trial concluded on 14 June 2020 and the membrane trial concluded on 23 June 2020 and was restarted during the summer of 2020/2021 with the aim of capturing a significant lake snow event in Lake Dunstan.

2.2 REQUIRED TREATED WATER QUALITY

The 2017-2018 annual compliance report prepared by the Drinking Water Assessor (DWA) records that the Clyde water source (and by inference the LDWS system) requires a minimum of 4-log protozoa treatment.

In mid-2019 CODC confirmed the desire to pursue a treatment solution which provides 4-log inactivation for protozoa, with residual chlorination to achieve bacterial compliance.

In addition to the treatment process units identified in Section 2.1 above, additional units are also required to ensure compliance with the DWSNZ. The required process units and their associated protozoal log-credits are shown below:

Table 1: Piloted Water Treatment Processes and their respective log credits under DWSNZ

Options	**WTP Process**	**Protozoa log credits**
1 – Cartridge Filtration	Arkal Spin Klin[Note 1]	0
	Amiad AMF[Note 1]	1[Note 2]
	Cartridge filters	2
	UV	3[Note 3]
	Chlorine	0[Note 4]
	Total	**6**
2 – Membrane Filtration	Membranes	4 [Note 5]
	Chlorine	0 [Note 4]
	Total	**4**

Notes

1. The Arkal/Amiad are utilised as pre-treatment units to prolong the life of the cartridge filters.
2. The Amiad AMF has been NSF-419 tested to a minimum of 2-log protozoa credit and received draft notification from the Ministry of Health (MoH) on 7 July 2020 that the Amiad AMF will receive accreditation of 1-log protozoal credit.
3. Manufacturer dependent. 3-log inactivation is the maximum allowable under Section 5.16 of DWSNZ.
4. Required for bacterial compliance under section 4 of DWSNZ. NB: Alternative methods of complying.
5. Manufacturer dependent. Typically, membrane plants achieve a 4-log inactivation under Section 5.11 of DWSNZ.

2.3 PILOT TRIAL OUTCOMES

Key observations and findings from the cartridge pilot trial (Option 1):

1. Pre-treatment provided by the Arkal/Amiad system was unable to extend the run time and prolong the life of the cartridge filters by any appreciable timeline. The maximum run time was 4 days at a target flow rate of 1.4 L/s.
2. Pre-treatment provided by the Arkal/Amiad system reduced the raw water turbidity during the trial by more than 50% using the 2 µm AMF cassettes and by more than 70% using the 1.5 µm AMF cassettes. In both cases the AMF outlet turbidity was typically less than 1 NTU when feed water turbidity was low, however higher outlet turbidity (>2NTU) was observed during wet weather events.
3. To comply with the Drinking-water Standards for New Zealand 2005 (Revised 2018) (DWSNZ) for protozoa and bacteria, the treated water leaving the plant must meet the required quality criteria. Based on the observed reduction in turbidity through the Arkal/Amiad system and storage proposed at the water treatment plant, DWSNZ compliance is not possible year-round under Option 1. Non-compliance associated with achievement of protozoal log-credits for UV disinfection would have occurred at least six times for a period of 1 – 17 hours in the last 18 months. Non-compliance associated with achievement of the protozoal log credit for cartridge filtration (Amiad AMF) would most likely have occurred more frequently due to the more stringent turbidity requirements.

Key observations and findings from the membrane pilot trial (Option 2):

1. Reduction in raw water turbidity by significant margins, and consistently for the duration of the trial. During the high turbidity weather event described above, the membrane reduced the turbidity from 13NTU to less than 0.1NTU, as required under the DWSNZ for a membrane system to demonstrate protozoal log-credits.
2. Reduction in algae concentrations to below the detection limit. The presence of lake snow has yet been confirmed and it is unfortunate that site establishment delays and the Covid restrictions prevented the trial from being undertaken during periods when lake snow is known to be more abundant. Further laboratory and lake snow tow results are awaited to determine the quantum of lake snow in Lake Dunstan.
3. When the plant was fed with bore water for a period of about 2 months, it was able to operate at an optimised 100 LMH (maximum module capacity), with backwash intervals of 40 minutes, and a weekly chemical clean. When the plant was fed with lake water (i.e., higher Lindavia), it was able to operate at 80 LMH, with backwash intervals of 30 minutes, and a weekly chemical clean. An extensive cleaning cycle known as CIP was not required during the first 4 weeks of operation, and fouling could be mitigated with the weekly chemical clean. However, after completion of the official trial reporting period on 23 June, the plant continued to operate, and the membrane experienced increased fouling on 26 June. This resulted in requirement for a daily chemical cleans which was not successful at mitigating the fouling. A CIP was then undertaken on 6 July which did successfully mitigate the fouling. Test results from the

Otago Regional Council indicated that there were no significant amounts of "lake snow" within Lake Dunstan during this period.

In addition to the above outcomes, the following is noted:

1. Clyde Bore and Bore 1 installed within the constructed embankment have so far demonstrated good filtering of lake snow. It isn't clear if this will be observed to the same extent on Bore 3 nor is it clear if lake snow may break through the embankment in the future.
2. Raw water sampling confirmed low concentrations of dissolved iron and dissolved organics. The requirement for coagulant chemical dosing and/or pre-treatment upstream of the membranes as part of initial works was therefore excluded.
3. Further treatment trials are recommended at other localities in Central Otago to challenge test the pilot plant under high lake snow conditions.

Following the success of the membrane pilot trials and subsequent confirmation of the treatment technology for the scheme, the preliminary design of the water treatment plant and wider scheme has been finalised and detailed design is now underway. Further investigations outcomes and design outcomes are discussed in subsequent sections.

2.4 MODELLING AND DESIGN FLOW BASIS

The initial design flow basis developed in 2015 specified peak day demands of 18 MLD and 27 MLD by 2028 and 2048 respectively. Analysis of bulk meter data for the towns of Clyde and Alexandra from 2018 has allowed for further refinement of the scheme's calibrated model. Future demand network modelling to 2053, when combined with increasing the storage at Alexandra Northern Reservoir from 2000 m^3 to 6000 m^3 has allowed for significant reductions to the required scheme flows. The revised peak day scheme design flows are therefore 14 MLD and 21 MLD by 2028 and 2053 respectively.

By contributing to development of a robust hydraulic model, ensuring accuracy of flow measurement data, and making best use of this data, significant capital cost savings have been realized.

All elements of the scheme have been designed with the goal of minimizing the number of start and stop operations on the raw water abstraction bore pumps and the water treatment plant with the goal of minimizing associated operational costs and risks.

3 SCHEME DESCRIPTION

The high-level components that make up the scheme and some of the key features are outlined as follows:

3.1 RAW WATER ABSTRACTION

The raw water for the water supply scheme is sourced via three bores installed within a constructed embankment on the shores of Lake Dunstan. This effectively acts as a gallery inlet with some filtering of sediment and other particulate contaminants via the embankment soil structure (discussed further below). Bore pumps with motors ranging from 94 to 110 kW are installed in 400 mm casings to depths of up to 25 m. The pumps convey the raw water via a combined 500 mm PE pumping main some 50 vertical m and 800 m away up to the 250 m³ feed tank and water treatment plant (WTP) located in the shoulder of Clyde Hill.

3.2 WATER TREATMENT PROCESS

Raw water is drawn from the feed tank via 55 kW KSB pumps dry mounted within the WTP building. The KSB pumps provide sufficient pressure to drive the raw water through self-backwashing Amiad strainers, Pall microfiltration membrane rack and up to the treated water tank. The Pall membrane racks each comprise 80 modules, with each module comprising of 6,000 hollow core microfiltration membrane fibers. Hypochlorite dosing and associated monitoring equipment is provided on the discharge from the WTP. The WTP building also houses the membrane backwashing and chemical cleaning systems, hypochlorite dosing systems, associated chemical storage, electrical and controls equipment and ancillary equipment.

3.3 TREATED WATER TANK

The WTP discharges to the top of the 750 m³ treated water tank (TWT) approximately 150 m away via a 560 mm PE rising main. The TWT provides for chlorine contact time and operational control of the WTP according to the downstream demand at Clyde and Alexandra.

3.4 RESERVOIRS AT CLYDE AND ALEXANDRA

Treated water flows under gravity to the Reservoirs at Clyde (~300 m distance) and Alexandra (~9500 m distance) via PE pressure pipelines. Electrically controlled hydraulic flow control valves are installed on the inlets to each reservoir site allowing for variable filling rates according to water level in the reservoirs. Electrically actuated outlet flow control valves are provided at the reservoir sites to automatically provide throttled outlets in response to significant bursts in the network and to allow for remote isolation of reservoir outlets following a significant seismic event.

4 COORDINATED DESIGN APPROACH

The raw water quality and treatment objectives have driven the need for suitable pilot trials and the outcomes of the trials and other key investigations have largely directed the design process adopted on the scheme. The membrane treatment technology selected following the pilot trials has allowed for progression of the WTP design and development of the basis of design for the various inter-related scheme components including backwash waste stream, chemical waste stream, chemical waste neutralization, chemical deliveries, WTP hydraulics from raw water tank and to the treated water tank, building layout and electrical and control systems. These are further discussed in section below.

The coordinated designs for the project are bringing in several organisations to make best use of existing knowledge available in the district and wider industry. Where possible the components designs are led by the organisations that are fulfilling the Contract physical works and further critical input is being sought from industry leaders throughout the world. Some examples of contributions from the organisations involved are as follows:

- Pall Marshall Water Consortium (PMWC) - WTP Process designer and proposed Process contractor
- Switchbuild - Systems Integration, SCADA and Controls designer and proposed subcontractor
- Fulton Hogan – Operations and Maintenance contractor
- Fulton Hogan - proposed civil and main contractor
- Central Otago District Council – Asset Owner representation and operations and project management
- Stantec – lead scheme designer, civil designers and project coordination

This coordinated design approach is allowing for risk reduction, clear risk allocation and opportunity enhancement prior to confirmation of the physicals works contract. The early engagement and resulting clarity of scope and risk awareness has increased buy-in with all parties working collaboratively towards successful delivery of this significant project.

Importantly for the communities served by the scheme, this approach is helping to deliver the project when the engineering sector is arguably having difficulty providing sufficient technical resources necessary to deliver the scale of infrastructure investment needed for New Zealand.

5 VALUE ENGINEERING AND FUTURE PROOFING BENEFITS

5.1 SITE LAYOUT OPTIMISATION

The feasibility stage design for the water treatment plant included a filtrate buffer and filtrate booster pump station upstream of the treated water tank. This was required as the proposed treated water tank elevation and resulting hydraulic grade level at the water treatment plant exceeded the allowable operating pressure of the membrane racks. Subsequent detailed inspection of site contours between the water treatment plant and potential treated water tank locations allowed for different positions and cut to fill works to be identified which removed the additional buffer storage and pumping equipment. This design change was made possible by challenging the previous design basis on the scheme and by engaging with the specialist process contractor to understand the equipment limitations.

5.2 WASTE STREAMS

The waste streams from the water treatment plant are separated into backwash waste, which effectively contains concentrated lake sediment and contaminants present within the lake and/or bore water; and chemical waste, that covers water contaminated with sodium hypochlorite, sodium hydroxide and/or citric acid plus other particulate matter removed from the membranes through the chemical cleaning processes.

The feasibility design for the water treatment plant was based on membrane backwash waste going to the wastewater reticulation in Clyde. However, due to flow and treatment capacity limitations, a second stage of membrane filtration would have been required to reduce the backwash waste volumes from 400 m^3 down to approximately 50 m^3 at the 2028 design horizon. This would have resulted in significant capital and operations costs for the scheme. Subsequent discussions between CODC and the Otago Regional Council (ORC) yielded confirmation that the discharge of backwash waste to the Clutha River would be considered a permitted activity subject to conditions being met regarding dilution and maximum concentrations of contaminants after reasonable mixing. Discharge dilution assessments are proposed and underway and are expected to yield confirmation of acceptable discharge conditions. This is expected to provide for significant capital and operational cost savings on the project and highlights the clear benefits of engaging proactively with consenting authorities early in the project lifecycle.

The main constituent from the WTP chemical waste stream that is expected to exceed the permitted concentrations in CODC's draft Trade Waste bylaw is chlorine. Sodium hypochlorite is used in the weekly enhanced flux maintenance (EFMs) and in the monthly Clean in Place (CIP). Citric acid and sodium hydroxide are also used as part of the monthly CIPs. Provided the waste volumes are retained until the end of each cleaning cycle, it is expected that these acidic and basic constituents will neutralise with the resulting pH within acceptable levels. On this basis, the scheme basis of design included neutralisation of chlorine prior to discharge with Sodium metabisulphite or sodium thiosulphate. This would have required additional infrastructure within the WTP building and additional chemical storage tanks with reasonable cost implications. Subsequent discussions with CODC covering the new wastewater network within Clyde, resulted in confirmation that the chlorine within the chemical waste stream can be managed by protecting the concrete manholes immediately downstream of the discharge. After discharge to the wastewater network, it is expected that any residual free chlorine will be readily react with the carbonaceous material in the residential wastewater. On this basis it was agreed that neutralisation prior to discharge to the wastewater network is not required. In this instance re-examining the design requirements with the consenting authority and looking at different options to mitigate effects is resulting in significant cost savings to the project.

5.3 FUTURE PROOFING

5.3.1 WTP CAPACITY

The WTP has been specified and designed to allow for planned upgrades in the future to increase the design capacity of the WTP from the initial installed capacity of 14 MLD to the ultimate design capacity of 20 MLD by 2048. To this end spare space is allowed for within the building and pipework for an additional membrane rack, feed pump and strainer to achieve the higher flow duty.

Space is provided within the membrane racks for 10 addition membrane modules to allow for potential deterioration in raw water quality and associated potential requirement to reduce the membrane flux rate. Subject to potential pumping upgrades in future it may also be possible to increase the output of the WTP by increasing the modules per rack.

A key output from the pilot trials was to confirm the design flux rates that the membranes will operate at. The pilot plant was successfully operated at a flux rate of 100 LMH during the trial however the trial recommended the membranes are operated at a lower flux rate of 80 LMH to extend the time between backwashes and extend the time between CIPs. As the scheme design has been progressed based on a flux rate of 80 LMH, it may be possible to increase this in future and if combined with larger feed pumps could allow for an increased WTP capacity.

The successfully trialed 100 LMH flux rate was achieved using direct source lake water in an attempt to challenge test the membranes. As the WTP will operate with bore water as the raw water source, the bankside filtration available will offer additional protection against from poor water quality in the lake and further protect the capacity of the WTP.

5.3.2 WTP PRE-TREATMENT

As discussed in the Section 2.3, it was not possible to confirm acceptable performance of the microfiltration membranes and associated cleaning regime with raw water containing reasonable concentrations of lake snow derived from the Lindavia diatom algae. If lake snow were to break through the bankside filtration afforded by the bores, it is expected that this will lead to increased backwashing and chemical cleaning. The extent of which is not known however this may result in reduced throughput at the WTP below the required capacity and/or chemical consumption costs may become unreasonably high. If this scenario does eventuate in the future, space has been provided for at the WTP site for later installation of a dissolved air filtration (DAF) pre-treatment system which is expected to provide good removal of diatom algae and the associated lake snow polysaccharides.

5.3.3 FLUORIDE DOSING

The recent change to move the decision-making power for fluoride addition for water supplies from local governments to local/regional or national health boards is expected to result in fluoride addition to water supplies to be mandated. Space has therefore been provided to allow for the addition of fluoride dosing at the WTP in future.

5.3.4 TREATED WATER TANK REDUNDANCY

The scheme hydraulic design means that the treated water tank can't be taken out of service for prolonged periods of time for maintenance or inspections without unacceptable disruption to continuity of supply. It is noted that the projects construction and commissioning plans will address this risk in the short to medium term as much as possible however to address this risk in the long term a methodology of bypassing the TWT is required. To facilitate for this later work, space and connectivity is provided at the treated water tank (TWT) site to allow for the addition of a second 750 m^3 TWT in future. This will enable either TWT to be taken out of service for inspections and potential repairs if required. The additional storage obtained from this will also improve the resilience of the scheme to unplanned WTP plant outages that may occur.

5.4 RESILIENCE AND REDUNDANCY

Several key outcomes from the design process and HAZOP will ensure reliable and resilient operation of the Lake Dunstan Water Supply scheme. Some of these are noted briefly below:

5.4.1 EQUIPMENT REDUNDANCY

To ensure flow continuity during planned or reactive maintenance events where possible equipment has been specified to provide for full (N+1) level if redundancy at the nominated scheme design flow rates or otherwise down times for repairs or to undertake replacement works has been confirmed possible within the allowable outage timeframes of the downstream processes.

5.4.2 COMMUNICATIONS AND INSTRUMENTATION REDUNDANCY

The safe and reliable operation of the water supply scheme is dependent on continuous communications between multiple sites and numerous instruments as follows:

- The raw water bore pumps rely on reliable relay of level in the raw water tank via the WTP PLC
- The flow pacing of the WTP relies on reliable relay of level in the TWT
- Minimum filing rates at the reservoir sites at Clyde and Alexandra rely on communications between these sites
- To ensure acceptable chlorine contact time int TWT, interlocks are provided to isolate the inlet control valves at the reservoir sites in the event of low water level in the TWT.

To ensure acceptable operation of these data links and operation of the scheme:

- fibre optic connectivity will be established between all sites as the primary communications method and cellular radio will be provided as backup communications link.
- All critical level instrumentation in the tanks and reservoirs are installed in duty/standby configuration with alarms provided on disparate readings.

5.4.3 STANDBY POWER SUPPLIES

Standby diesel generators with eight hours of fuel storage at peak load and uninterruptible power supplies (UPSs) with 2 hours of battery life will be provided at all sites to protect the scheme from power outages. All sites will be provided with the ability to automatically return to supply following powering up of standby diesel generators. All instrumentation, alarms and communications will be powered by UPSs to ensure continuity of information for operators through power cuts or disaster scenarios

6 CONCLUSIONS

As the project has progressed, technical details have been defined, investigations and pilot studies have yield outcomes and results, all of which have required that the project delivery methodology is adapted to suit. The consistency of change and the need to adapt on complex projects such as this is commonplace. Recognizing this and allowing for it with project delivery plans and programmes wherever possible is critical.

Allowing for changes in source water quality or treatment requirements, where possible is critical as we see significant changes to the regulatory setting and/or natural environment that these systems are constructed within. Potential changes in New Zealand's freshwater ecosystems in response to a changing local and regional climates or invasive species will necessitate greater flexibility in our engineering solutions to water treatment in years to come.

The successful delivery of large complex projects like water supply schemes with multiple sites, specialist treatment systems, inter-linked control systems and multiple disciplinary design elements requires that many technical experts work together with the common goal. With expectations of operating within a resource constrained industry, it is expected that we will increasingly rely on specialist knowledge coming from different organisations including consultancies, civil contractors, specialist subcontractors, O&M contractors, and asset owners. The Lake Dunstan Water Supply project is an example of this where eight different organisations are contributing to a collaborative design.

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REFERENCES

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